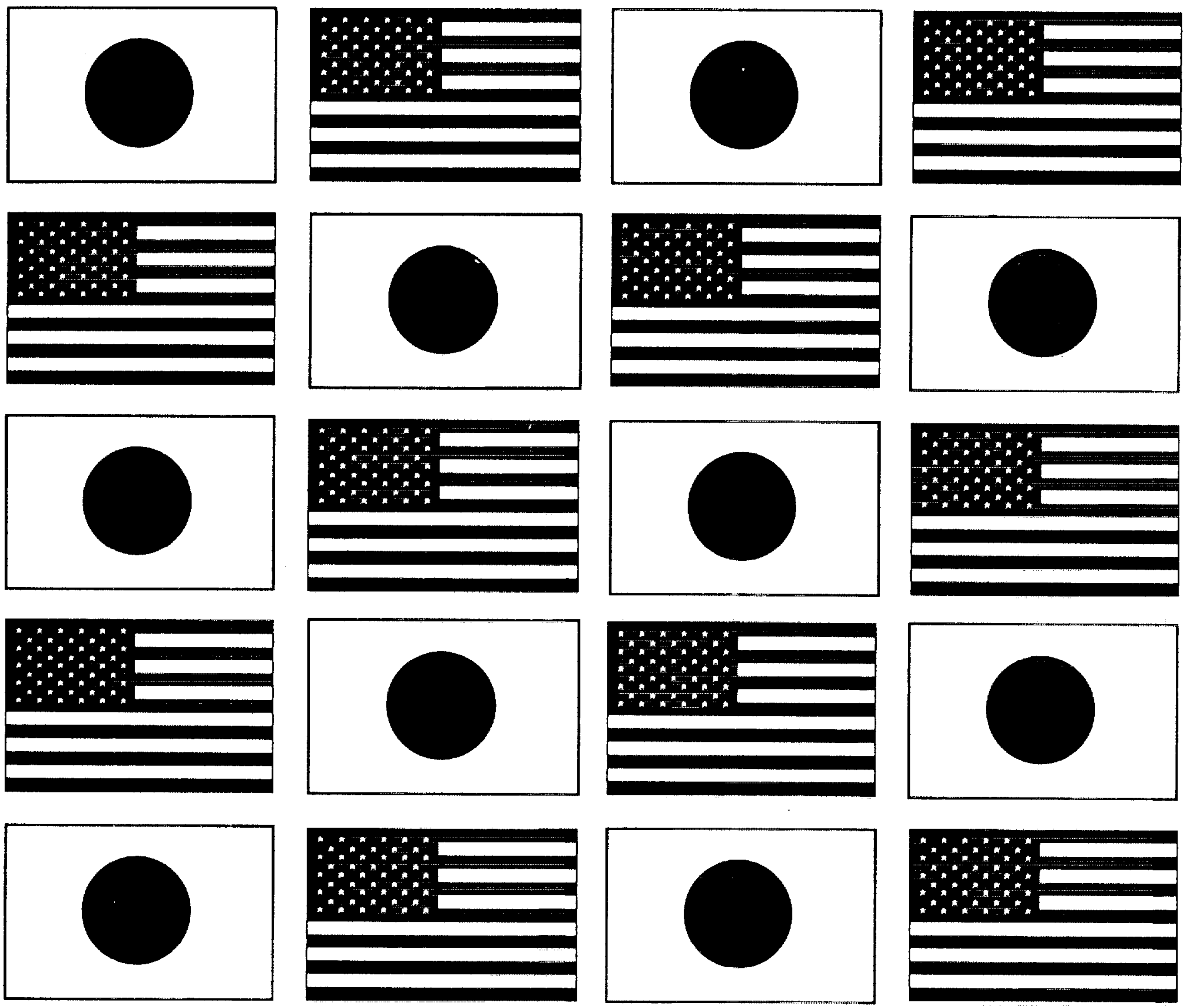
Wind and Seismic Effects

Proceedings of the 30th Joint Meeting

NIST SP 931



U.S. DEPARTMENT OF COMMERCE
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Wind and Seismic Effects

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PROCEEDINGS OF THE 30TH JOINT MEETING OF THE U.S.-JAPAN COOPERATIVE PROGRAM IN NATURAL RESOURCES PANEL ON WIND AND SEISMIC EFFECTS

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REAL TIME INFORMATION ACQUISITION and DISSEMINATION

SEISMIC INFORMATION SYSTEM FOR CIVIL INFRASTRUCTURES

by

SUGITA Hideki [1], NOZAKI Tomofumi [2]

ABSTRACT

This paper describes comprehensive image of the seismic information system (SIS). Two points are included in the paper: i.g., a new system architecture to realize SIS with systematic control, possibility of extension and the independence of the subsystems, and several element technologies applicable to the subsystems of SIS. The proposed concept does not only concentrate on the technologies of the supply-side, but also the philosophy and the technologies that is "objective oriented." As the counter-earthquake activity system is responsible many complex jobs at a time, and as the information technologies is becoming highly technical, the concept introduced here is very much help for the personnel of the counter-earthquake activity system.

Key Words: Counter-earthquake activity system, Information system, New technology and philosophy

1. INTRODUCTION

Since the Hyogo-ken Nanbu Earthquake, which revealed the necessity for quickly monitoring damage, communicating information, and making decisions, many organizations have constructed various systems to deal with earthquake information, which are listed in Table 1-1. Their principal functions are to:

1) monitor, collect, and adequately display accelerograph measurements and data from other organizations and systems (*observation and collection*),
2) estimate the damage to facilities and injury to people by the earthquake and consequent fires, from the data collected (*damage estimation*),
3) take emergency measures based on the data collected, and the estimated damage, such as immediate suspension of facility functions and warnings to users (*emergency response support*), and
4) support the decision making processes by presenting instructions given in emergency manuals and proposing optimum strategies (*counter-earthquake system support*).

So far, most of these systems are developed for use within the organization. Although each system remotely accelerographs, collects and communicates information through the network, and exchanges data between its submodules constructed for each function, it has its own independent database. When users encounter the occasion to exchange data between systems, they must conduct a series of complicated operations and must know the

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methods for operating the systems, which may differ by system. As such information systems usually use common earthquake motion measurements, ground condition and facility data, we should investigate methods for sharing such data without losing the possibilities for extension and independence of each system.

2. CONVENTIONAL APPROACHES FOR CONSTRUCTING SEISMIC INFORMATION SYSTEMS AND BREAKTHROUGH

2.1 Top-Down Approach

Most seismic information systems have been constructed with a top-down approach. For example, a system that 1) collects ground motion data, 2) estimates human casualties and fire occurrence from the data, and c) suggests the actions necessary for preventing damage is designed to include all these functions in one host machine as shown in Figure 2.1. Although it is possible to supplement functions to the system later, the top-down approach fundamentally creates the image of an entire system first. Hence, the top-down approach has disadvantages such as

1) a system does not operate until the whole system is completed,
2) it is difficult to renew the system, since a slight change may largely affect the entire system (thus such systems easily become obsolete), and
3) all users within an organization must fully know the provided operation method.

2.2 Bottom-up Approach

A new movement is occurring in the

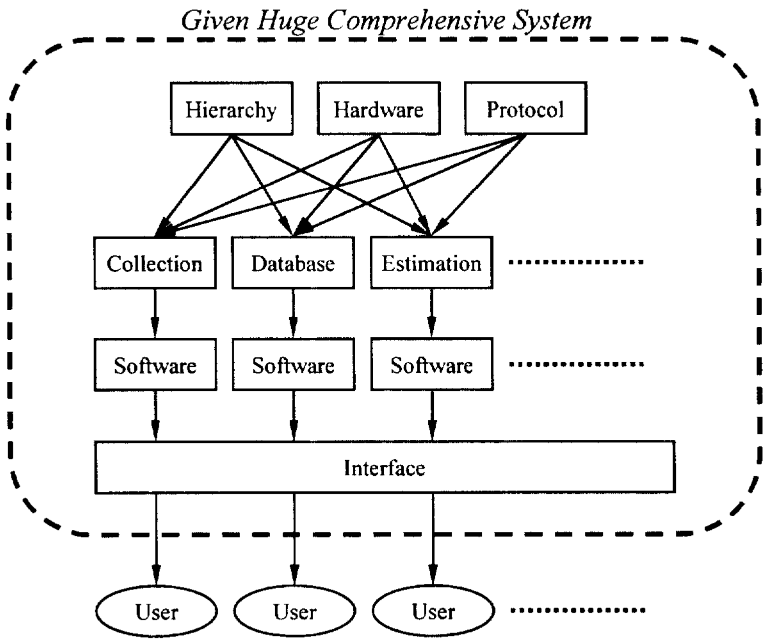

Figure 2.1 Top-down Approach

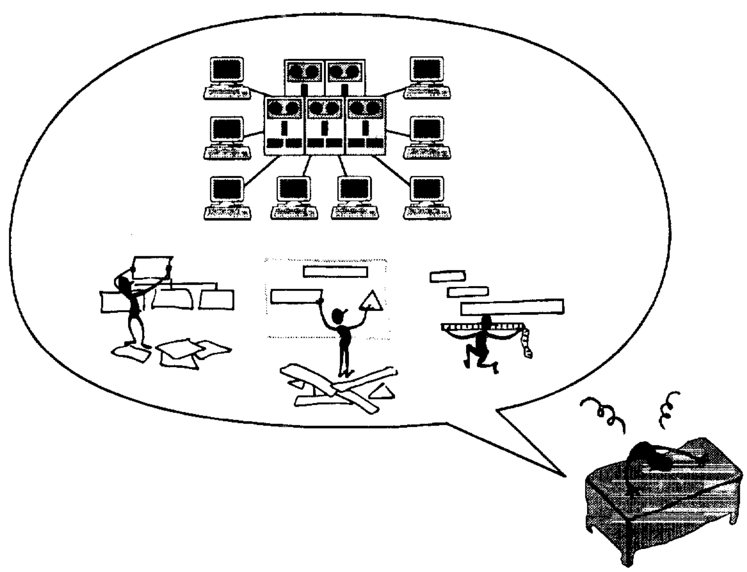

Figure 2.2 Disadvantage of Top-down

construction of information systems along with the recent development and diffusion of information network technologies, such as the internet. In the WWW, for example, each terminal freely constructs a server according to a minimum set of integrated rules including the TCP/IP protocol, and communicates information to many and unspecified clients. Such a state forms a contrast to the above top-down approach in terms of flexibility and possibilities of extension of each function of servers. This construction method is called the bottom-up approach.

With the bottom-up approach, it is possible to construct a database and run an application on one server as its administrator hopes. Other persons can use the same system by using a browser or other similar software. When the administrator needs a new function, he/she only either adds the desired function to the server or supplements a new server. In this situation, there is no need for considering other users. However, systems constructed with the bottom-up approach are inappropriate for systematic activities since servers usually use different functions and data independently.

2.3 Breakthrough

The top-down approach constructs systems that share data and functions but are not flexible or free. On the other hand, the bottom-up approach constructs systems that are easy to add new functions and to access but may not be using common data. These two approaches are both extremes of system construction (or system formation). By integrating the advantages and characteristics of both, a new and more efficient method for constructing seismic information systems (SIS) may be developed. The ideas are summarized as follows:

1) It clarifies the minimum set of information

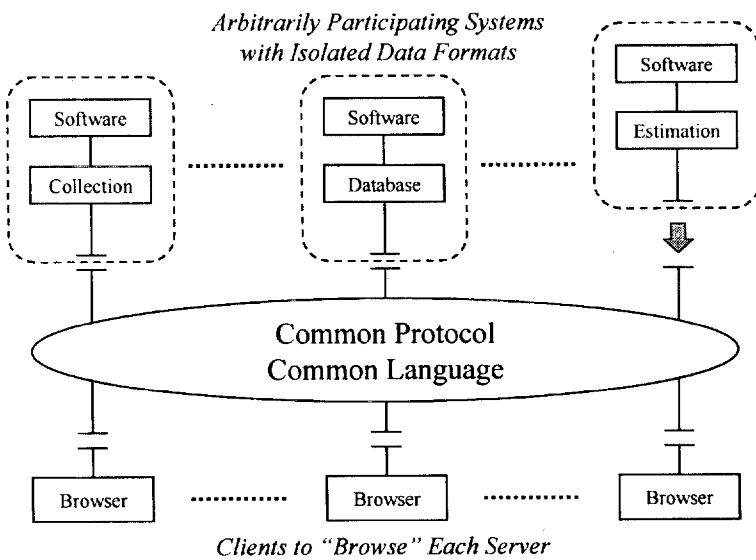

Figure 2.3 Bottom-up Approach

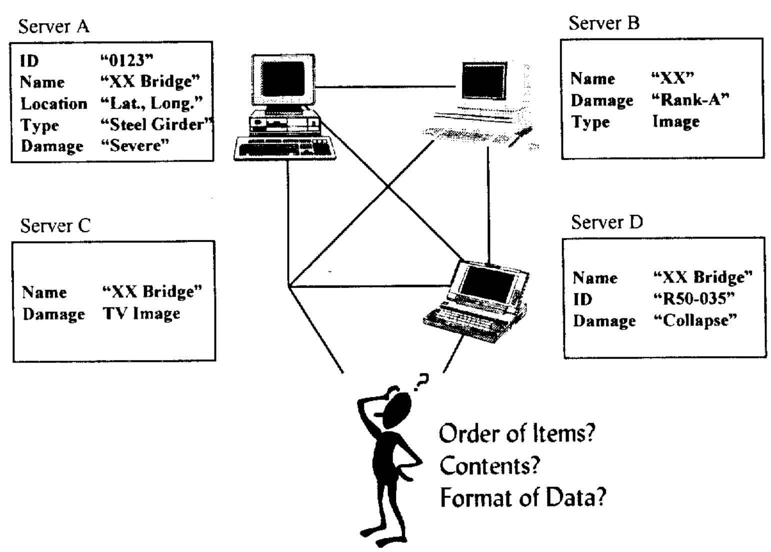

Figure 2.4 Disadvantage of Bottom-up

that is needed for each level of an organization. The information that is open to a level is also open to lower levels (*data sharing*).

2) All divisions that have acquired permission can operate or refer to outputs of SIS with shared data (*function sharing*).

3) A certain level of an organization can supplement its own data and function to the SIS (*system flexibility*).

To actualize these ideas, integrated methods should be developed and organized for sharing data and functions in different levels of an organization. The recent diffusion of network technologies has spread common protocols and software such as http and java applets. However, more precise data items and format definitions must be defined for using a large amount of data and functions needed for systematic counter-earthquake activities. The following alternatives may be adopted for sharing data and functions:

1) An entire organization uses one database and the same application software.

2) All databases are constructed with a single format (schema).

3) All databases contain at least a minimum set of data items, which make users possible to use the data by converting them with simple application software.

To make data accessible to all users, all organizations that use the SIS must clearly understand their duties concerning counter-earthquake measures and make lists of necessary information. Although such operations are labor consuming for the organizations, the initial cost in terms of money, time, and labor is sure to be well spent in constructing a more comprehensive, flexible, and organized system. Incidentally, Geographical Information Systems (GIS), which display collected data and

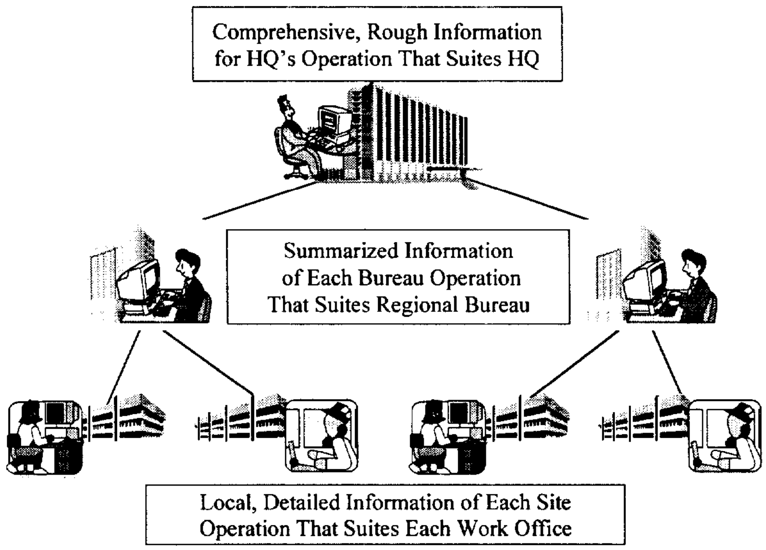

Figure 2.5 Data/Function Sharing

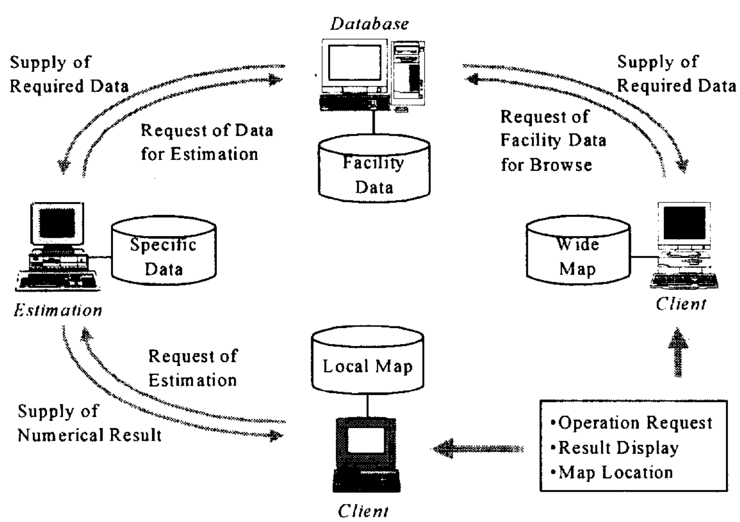

Figure 2.6 Breakthrough Technology

Table 2.1 A&D of Respective Approach

	Top-down	Bottom-up	Breakthrough
Development/Improvement Speed	slow	rapid	comparatively rapid
Possibility of Extension	small	large	comparatively large
Independence of Subsystems	Almost none	Almost independent	Independent under some control
Physical Cost in Development	Quite much	Small	Not much
Labor Cost	Large when studying manipulation	Responsibility of each server administrator	Initial coordination is required
Uniformity of Data	Secured	Difficult to establish	Secured when necessary
Systematic Development and use	Strict	Chaotic	Practical

estimations on maps, will be independent from the collecting and estimating procedures. In the approach introduced here, data interfaces can be jointly used even when GIS applications/data are different.

The advantages and the disadvantages are summarized on Table 2.1. According to this, strict coherence of the top-down approach, the incoherence of the bottom-up approach and the advantages of the proposed approach against others are clearly depicted.

3. FUNCTIONS, TECHNOLOGIES, AND APPLICATIONS OF SEISMIC INFORMATION SYSTEMS

3.1 Functions to be Included in Seismic Information Systems

This section summarizes functions to be included in SIS of organizations that administer civil infrastructures, such as the Ministry of Construction. The following functions are proposed to be included in SIS.

(a) Evaluation of counter-earthquake projects

SIS should help determine the priority of reinforcing projects, based on their influence over emergency activities and economic damage.

(b) Evaluation of counter-earthquake activity systems

SIS should help evaluate the speed and accuracy for collecting and communicating information of counter-earthquake activity systems.

(c) Monitoring, collection and estimation of earthquake data

SIS should collect characteristic values and wave data that are monitored and calculated by accelerographs and should estimate epicenters, etc.

(d) Support of anti-seismic activities

SIS should spontaneously inform of earthquakes, display manuals for emergency activities.

(e) Detection of facility damage

SIS should directly detect and communicate damage to public facilities by censors and so on.

(f) Real-time estimation of damage

SIS should quickly estimate the damage to facilities based on earthquake information and ground and structure data.

(g) Collection of inspection data

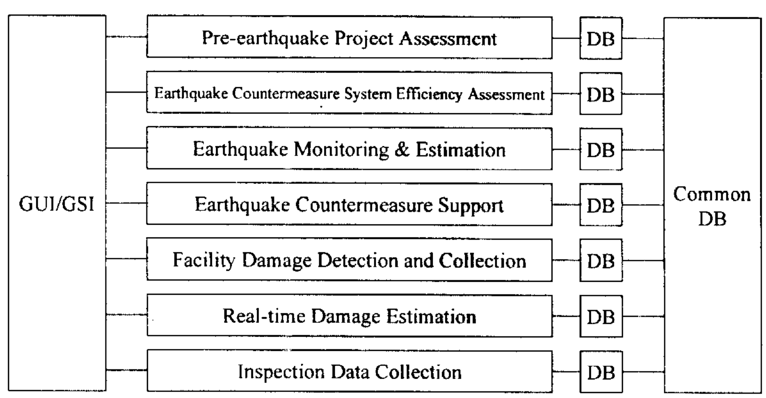

Figure 3.1 Functions of SIS

SIS should record and communicate actual inspection data collected at the sites.

(h) Display of maps, images, and animated pictures

SIS should have the interfaces to refer and input information appropriately.

(i) Communication of information (sound, images, animated pictures, and data)

SIS should transmit data through public and private telephone lines, facsimiles, internets, intranets, extranets, etc.

The following sections outline several technologies and systems that the Public Works Research Institute (PWRI) is developing. These functions, which are now independently studied, may be integrated into subsystems by coordinating data and by refining each function.

3.2 Accelerograph Network and Urgent Damage Estimation System

The Ministry of Construction has installed approximately 800 online accelerographs throughout Japan (accelerograph network) to help urgent inspection of its facilities, such as highways and river facilities, after earthquakes. This accelerograph network falls in the category (c) 'monitoring and collection of earthquake data' of Section 3.1. PWRI collects seismic information experimentally from approximately 100 accelerographs in the Kanto Area, and is developing a system for estimating liquefaction risks and bridge damage in this area. This system corresponds to the category (f) 'real-time estimation of damage.' Example displays of the system for maximum acceleration, estimated liquefaction risk, and estimated damage to facilities are shown in Figures 3.2 to 3.4. The system is also installed with a multiple-address device, which

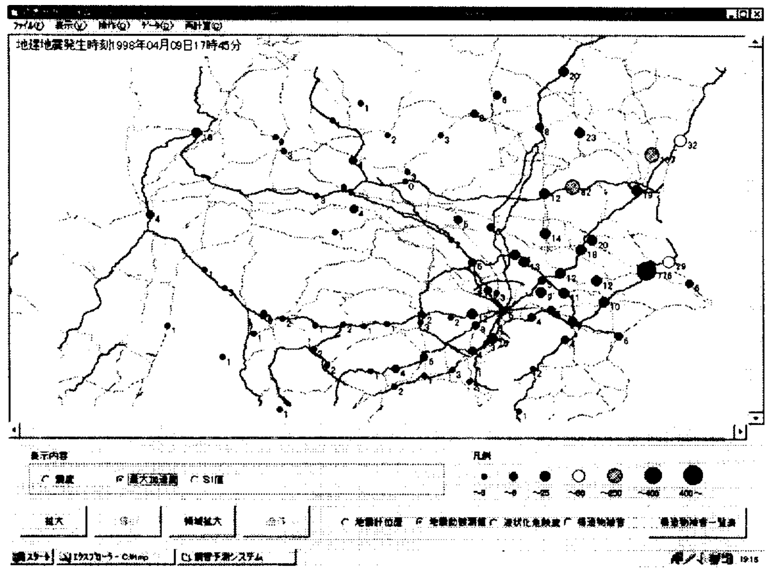

Figure 3.2 Estimation of Max. Acc.

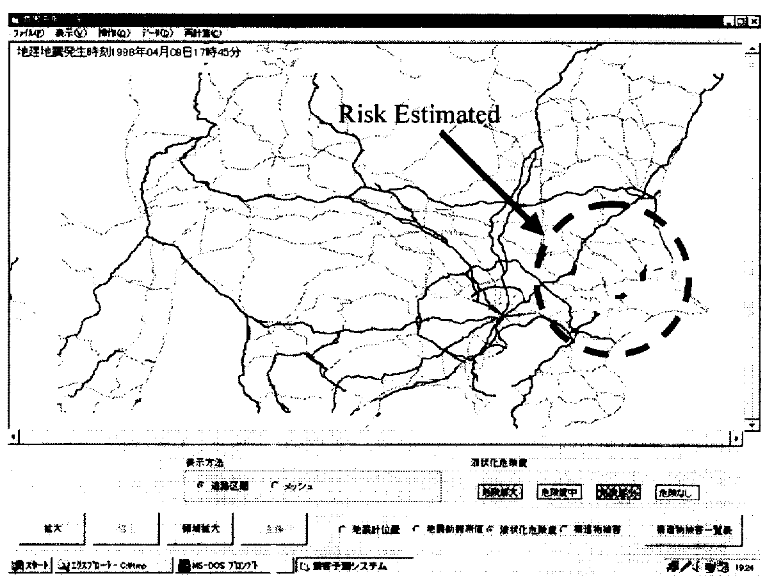

Figure 3.3 Estimation of Liquefaction Risk

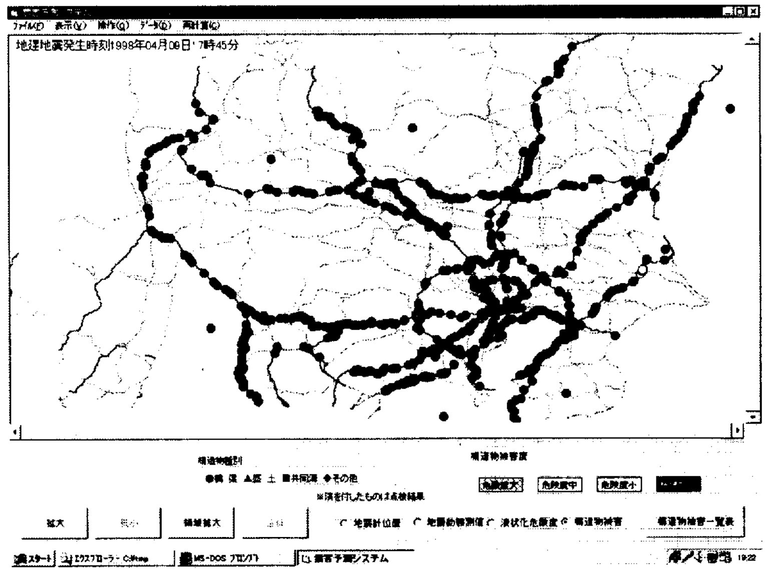

Figure 3.4 Estimation of Facility Damage

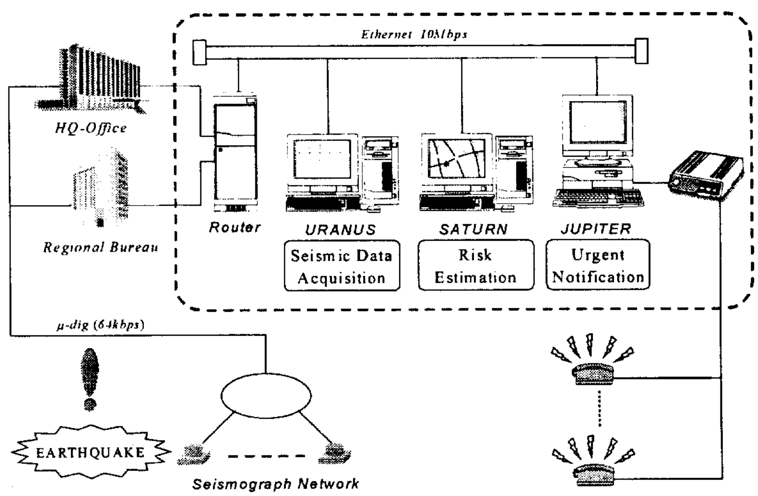

Figure 3.5 System Architecture

immediately and automatically dials all numbers registered when an earthquake occurs. This device corresponds to the category (d) 'support of anti-seismic activities.' A connection and operation diagram of the system is shown in Figure 3.5.

The characteristic values of earthquake motion (e.x., maximum acceleration and SI values) are transmitted from accelerographs immediately after the earthquake occurs and are recorded in files within a communication server. The urgent damage estimation system calculates liquefaction risks and facility damage levels based on these numerical files as well as ground and facility information collected in advance. The system also contains map data and can display the collected seismic data and the results of calculation on maps.

3.3 Earthquake Assessment System for Socioeconomic Effect (EASSE)

The earthquake assessment system for socioeconomic effect (EASSE) calculates quantitatively the mid-term and long-term economic losses by damage to transportation facilities, such as highways and railways. The

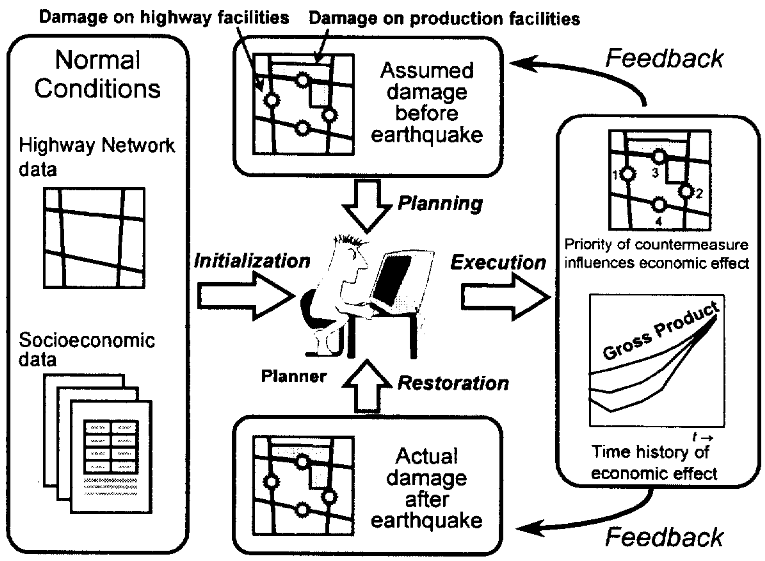

Figure 3.6 Idea of EASSE

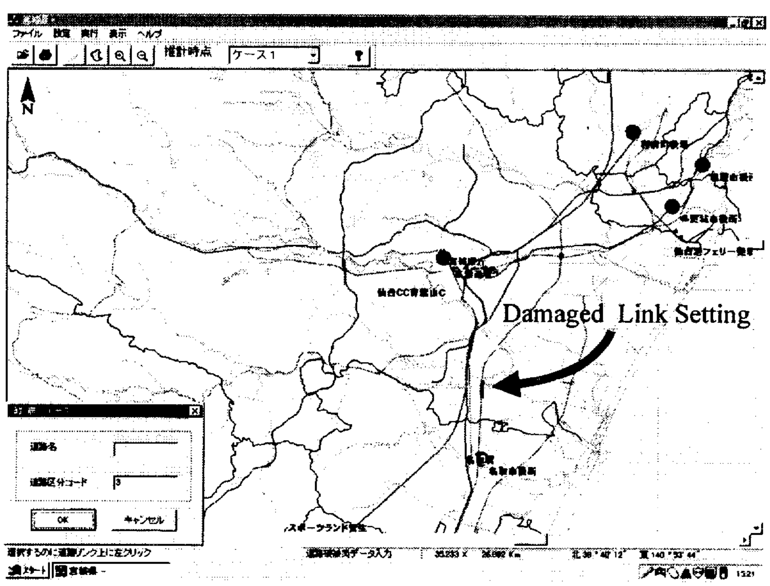

Figure 3.7 EASSE Display

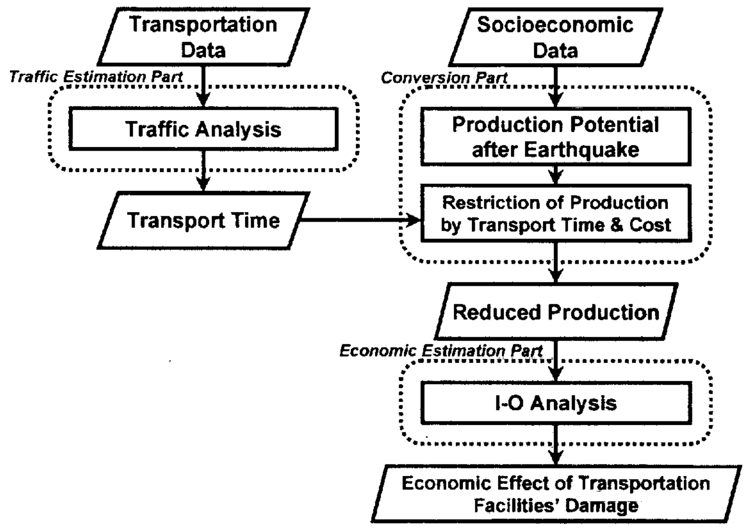

Figure 3.8 Module Structure of EASSE

PWRI has been developing a prototype for 3 years, from 1995 to 1997. As shown in Figure 3.6, this prototype system, which runs on a standalone PC, computes the drop in production due to damage to highway or railway sections input on a map display. Data for investigating reinforcement projects of transportation facilities in an area, such as the economic loss for each reinforcement pattern, are obtained simply by inputting damaged sections based on a hypothesized earthquake and reinforcement pattern. An example display for inputting damaged road sections and an output image are shown in Figure 3.7. EASSE, which falls in the category (a) 'evaluation of counter-earthquake projects,' may also be used for creating post-earthquake restoration projects. Since this system is now operating independently, it contains map data and also falls in the category (h) 'display of maps.'

For developing EASSE, the procedures necessary for estimation were converted into independent modules as shown Figure 3.8. The traffic estimation module calculates the increase in trip time by the earthquake based on highway-network data and socioeconomic data that are necessary for computing traffic demand. The conversion module calculates the drop in productivity in a target district from the results of the traffic estimation. The economic estimation module computes the effect of the drop in productivity in and out of the damaged district.

3.4 Seismic Performance of Highway Network

We should investigate if transportation facilities are able to serve satisfactorily even immediately after an earthquake. The seismic performance of the entire highway network should be studied to assure that no district is isolated by damage to highway sections and that disaster prevention activities are taken within a required period of time. PWRI is developing a system which calculates the degree of performance with which satisfactory prevention activities can be taken. The institute is also investigating a method for expressing the

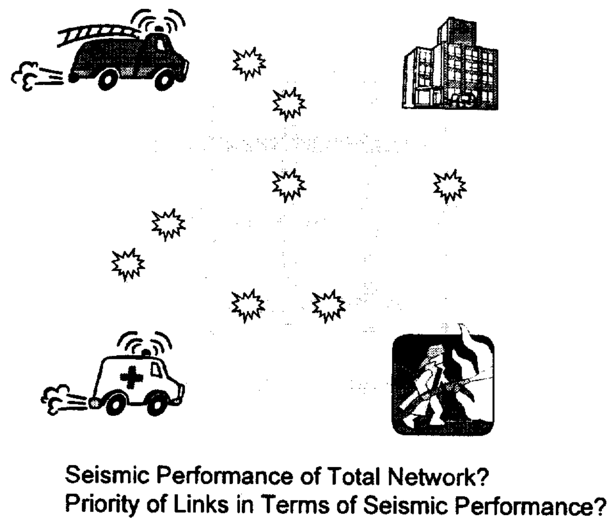

Figure 3.9 Network Seismic Performance

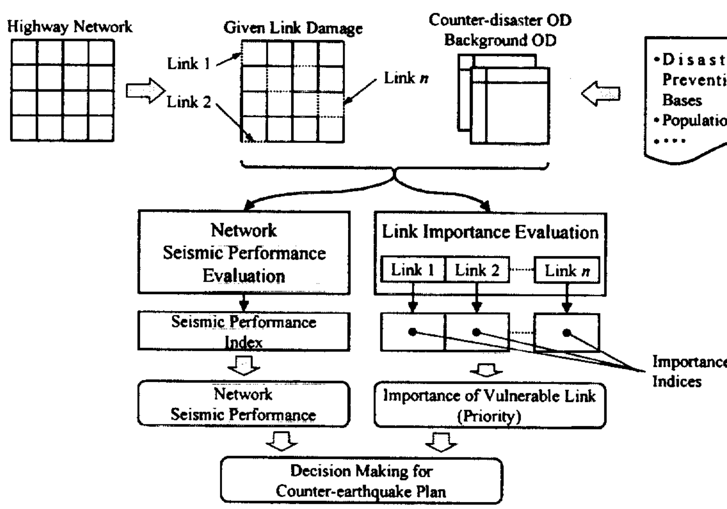

Figure 3.10 Flow of Calculation

importance of a damaged section quantitatively. Like EASSE, this system corresponds to the category (a) 'evaluation of anti-seismic projects.'

This system evaluates the seismic performance of the entire network and the importance of damaged sections when an earthquake disconnects the link of the network. The seismic performance of the network is calculated by computing the sum of disaster prevention activities' effects, which are determined based on the trip times of traffics in the network after the earthquake. A method is also investigated for calculating importance indices of network sections using the network seismic performance indices above.

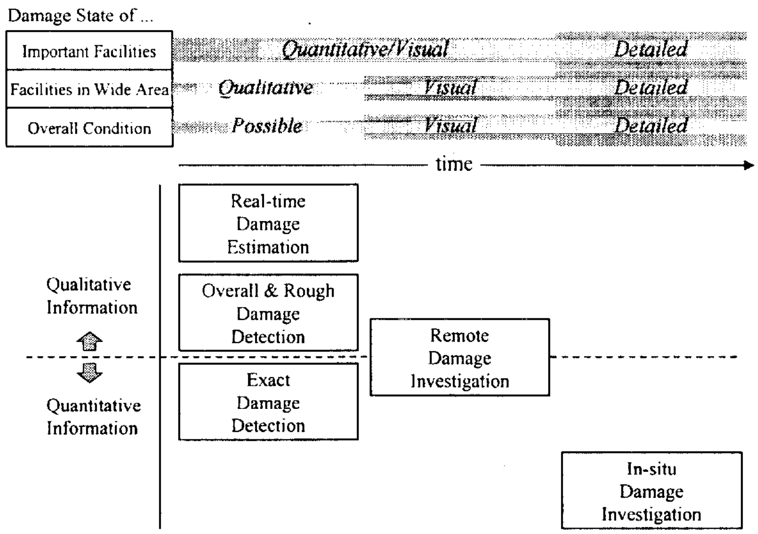

Figure 3.11 Combination of Damage Detecting Method

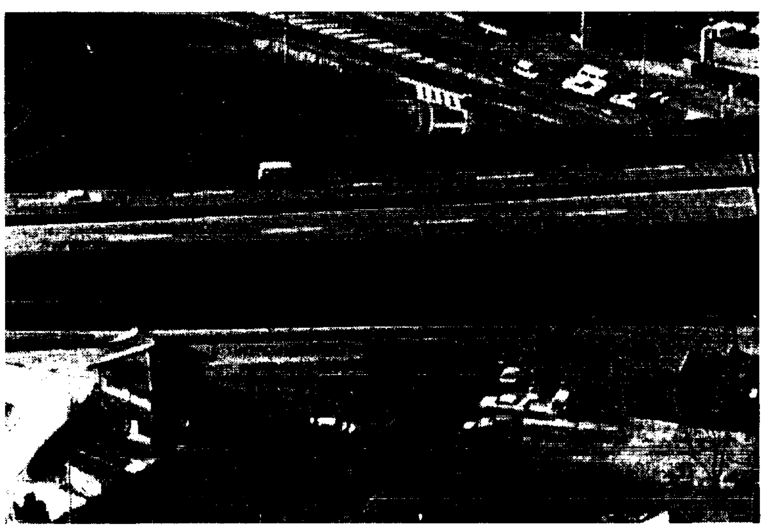

Figure 3.12 Example Image From Helicopter

3.5 Other Subsystems for SIS

Besides the subsystems' technologies and methods above, several other issues are studied which can be parts of SIS. Those include (1) earthquake damage detection technologies and (2) counter-earthquake activity system performance evaluation method.

The first one includes various technologies to detect the damage to infrastructures by utilizing sensors attached to them and remote sensing technologies. Some sensors such as laser distance meter can detect phenomena precisely, but they are expensive, while other sensors as wire cutting sensor are inexpensive and give only rough information of possible damage. Important facilities such as large bridges need to be watched carefully by sophisticated sensors. On the other hand, most of the facilities that stretch over wide area are enough to be observed roughly to detect possible damage. As for the remote sensing technologies, animated images taken from a helicopter and pictures sent from the investigation team directly are useful and important information to examine the restoration/rehabilitation strategies. Images from satellites are useful if they can be obtained immediately after the earthquake. Taking the these ideas into account, a menu for utilizing the damage detection sensors from the point of view of the cost, exactness and speed is studied as a guideline by PWRI.

Another useful method is that to evaluate the performance of a counter-earthquake activity system in terms of the rapidity and the preciseness to cumulate the damage information. In this method, all the personnel and equipment are expressed as abstract "gates" which transform the data from input and send to output. In the method, the information is defined as a combination of the

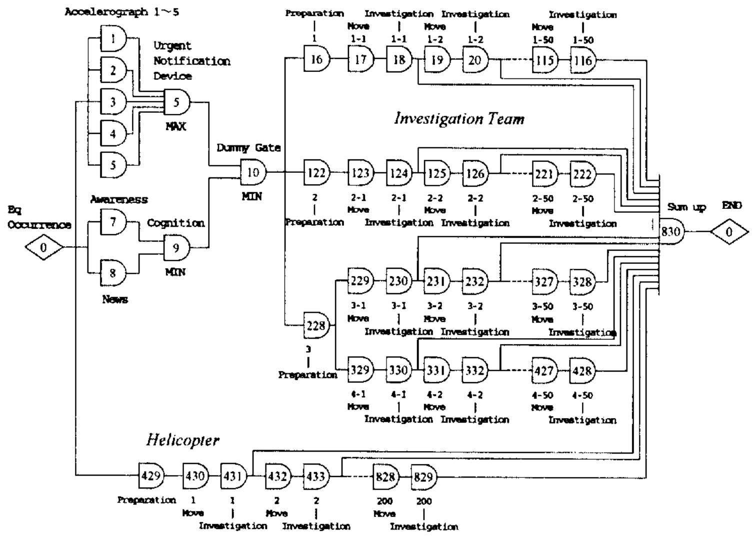

Figure 3.13 Network Expression of Counter-earthquake Activity System

time and the information quantity: i.e., (t, I). By defining the gates for all the entities in the system, and by connecting them with each other, the counter-earthquake activity system is expressed as an abstract network system. Analyzer can obtain the cumulating pattern of the information quantity and examine the performance of the system quantitatively. This also helps him/her to determine the bottle neck and the weak point part in the system.

4. CONCLUSION

The conventional SISs of the Ministry of Construction and most of other seismic systems under development are independent and do not share databases or map data. As described in Section 3.3, data should be shared and functions should be separated according to a minimum set of defined rules to create efficient and flexible systems. The methods for operating SIS must be familiar to the system staff since they must quickly treat an enormous amount of information after an earthquake. Using SIS in the normal conditions can improve the familiarity of the stuff. Rules concerning seismic information systems, common databases, and the development of independent functions are also helpful for the systems and functions used in the normal condition. By applying these concepts, we can construct a comprehensive system that is easy to use during both normal and earthquake times and to enlarge when necessary.

Because the idea introduced here includes comprehensive systematic regulation, it cannot be applied only by parts of organization, say, two or three work offices or regional bureaus. To realize the concepts here some adequate promotion system to coordinate all the organization must be established.

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Table 1.1 Example of SISs developed in Japan

Sytem Name	Organization	Monitoring	Damage Estimation	Emergency Response	Activity Support	Inputs	Notes
Disaster Information System	National Land Agency		O		O	JMA Seismographs	DIS
Rial-time Earthquake Damage Estimation System	Ministry of Construction	O	O			Seismograph	SATURN
Strong Motion Observation Network	Natl. Research Inst. for Earth Science and Disaster Prevention, Science and Technology Agency	O				Seismograph	K-net (Kyoshin-net)
Strong Motion Observation Network	Japan Meteorology Agency	O				Seismograph	
Seismic Intensity Observation Network	Fire-Defense Agency	O				Seismograph for Seismic Intensity	
Simple Earthquake Disaster Estimation System	Fire-Defense Agency		O			Seismic Conditions	
Seismograph Information System	Hokkaido Dev. Bureau	O				Seismograph	WISE
Earthquake Disaster Estimation System	Tokyo Fire Department	O	O			Seismograph	
Earthquake Disaster Countermeasure Support System	Kawasaki City	O	O		O	Seismograph	
Dense Array Strong Motion Monitoring Network	Yokohama City	O				Seismograph	
Seismograph Network	Tokyo Metro. Government	O				Seismograph	
Phonics Disaster Prevention System	Hyogo Prefecture	O	O		O	Seismograph	
Yokohama-city Disaster Prevention Information System	Yokohama City	O				Other Systems	
Disaster Image Transmitting System	Yokohama City	O				TV Camera	
UrEDAS/HERAS	Japan Railway	O	O	O		Seismograph	
Seismograph Network	Japan Highway Public Corporation	O				Seismograph	
Seismic Information Gathering and Network Alert System	Tokyo Gas	O	O	O		Seismograph, SI sensor, Liquefaction sensor	SIGNAL

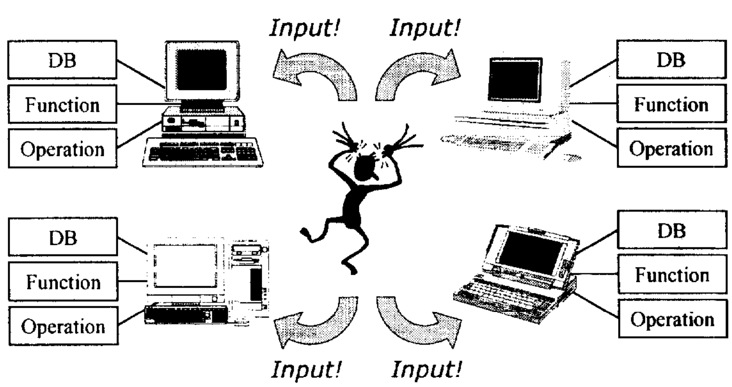

Figure 1.1 Isolated SISs